Thoughts on Enhanced Thermal Resource Accreditation

Ben Griffiths | NEPOOL Markets Committee, July 12-14 2022

About LS Power

LS Power is a development, investment and operating company focused on the North American power and energy infrastructure sector

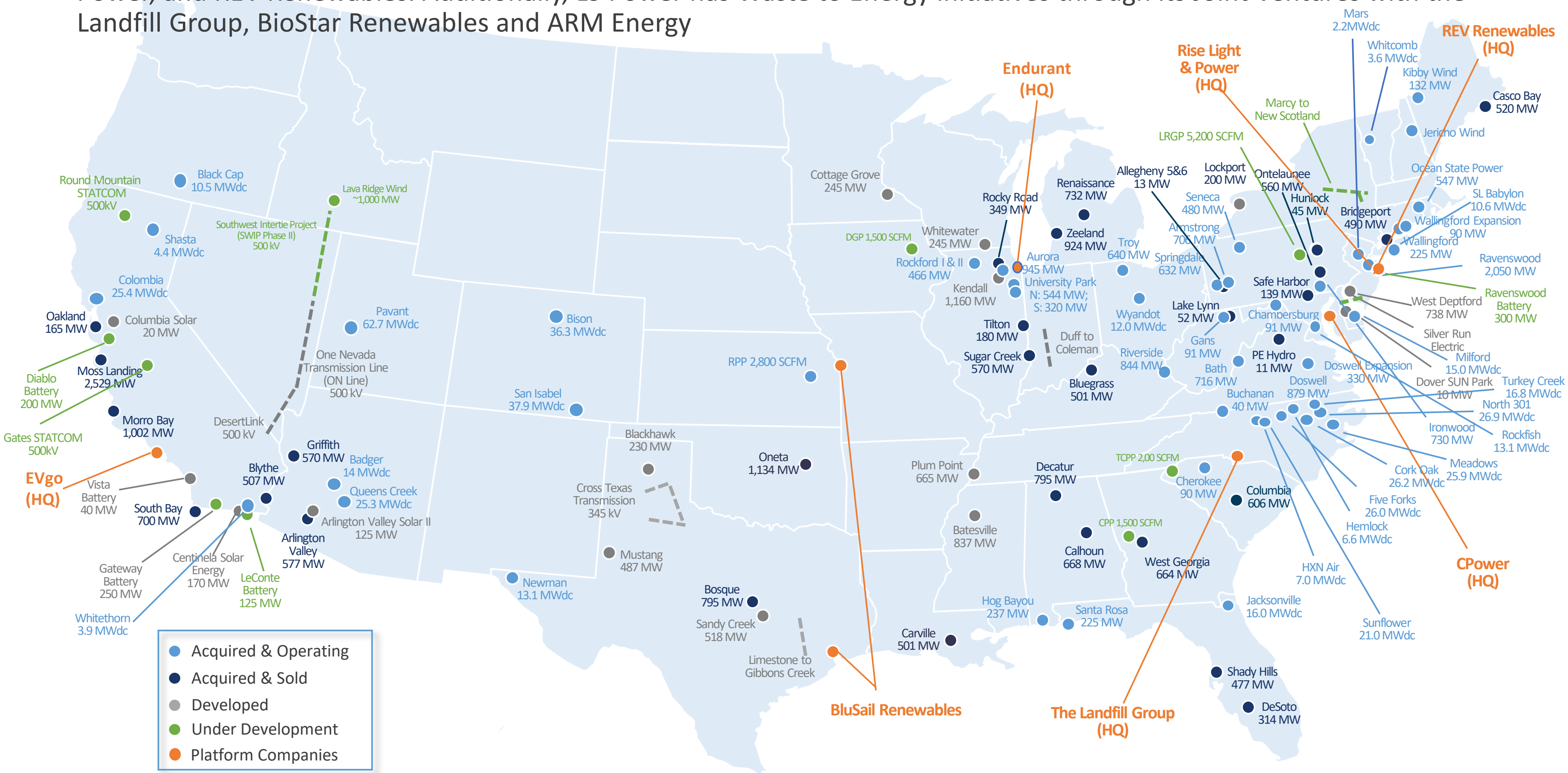
- Founded in 1990, LS Power has 280 employees across its principal and affiliate offices in New York, New Jersey, Missouri, Texas and California
- LS Power is at the leading edge of the industry's transition to low-carbon energy by commercializing new technologies and developing new markets.
  - **Utility-scale power projects across multiple fuel and technology types**, such as pumped storage hydro, wind, solar and natural gas-fired generation
  - **Battery energy storage**, market-leading utility-scale solutions that complement weather dependent renewables like wind and solar energy
  - **High voltage electric transmission infrastructure**, which is key to increasing grid reliability and efficiency, as well as carrying renewable energy from remote locations to population centers
  - **EVgo, the nation's largest public fast charging platform for electric vehicles** and first platform to be 100% powered by renewable energy
  - **CPower Energy Management**, the largest demand response provider in the country that is dedicated solely to the commercial and industrial sector
- Since inception, LS Power has developed, constructed, managed and acquired competitive power generation and transmission infrastructure, for which **we have raised over $47 billion in debt and equity financing.**
  - **Developed over 11,000 MW of power generation** (both conventional and renewable) across the United States
  - **Acquired over 34,000 MW of power generation assets** (both conventional and renewable)
  - **Developed over 660 miles of high voltage transmission**, with ~400 miles of additional transmission under development

Utilize deep industry expertise as owner/operator

LS Power Project Portfolio

Extensive development/operating experience across multiple markets and technologies

- With over $47 billion in equity and debt raised, LS Power has developed and acquired 120 Power Generation projects (renewable and conventional generation), 7 Transmission projects, and 5 Battery Energy Storage projects
- LS Power's Energy Transition Platforms includes CPower Energy Management, Endurant Energy, EVgo, Rise Light & Power, and REV Renewables. Additionally, LS Power has Waste to Energy initiatives through its Joint Ventures with the Landfill Group, BioStar Renewables and ARM Energy



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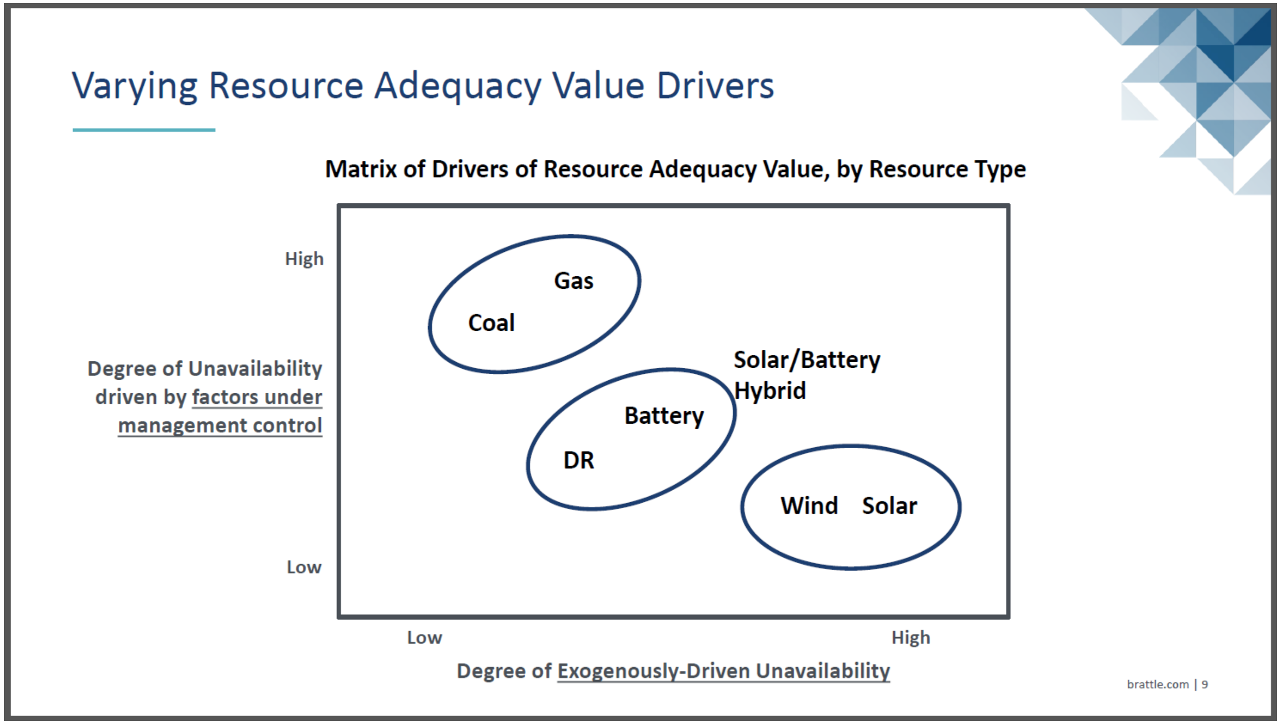
Position Summary

- Thermal resources are not all the same.
  - Thermal reliability is driven primarily by economic or management decisions, not external or uncontrollable factors.
  - Significant variability within and among thermal resource types.
- Proposals to apply ELCC-like accreditation mechanisms to thermal resources can obscure economic choices and may solidify the status quo by muting price signals.
- Prior efforts to extend ELCC-type methodologies to thermal highlight severe data limitations and double-counting risks; demonstrate difficulty of extending ELCC to resources where most variability is subject to management control.
- **Instead of developing an assumption-driven ELCC for thermal, it is preferable to refine the unit-specific "UCAP" concept and better align it with the treatment of variable renewables and storage.**

Techniques that can effectively capture reliability value of some resource types may be inadequate to measure others.



Newell, Higham, & Spees, *Understanding Capacity Resource Accreditation for New England's Clean Energy Transition,* presented to the MA AGO, 6-June-2022.

ELCC works for intermittent resources because performance is mostly determined by factors outside their control.

- ELCC for variable renewables is intended to predict expected output, coincident with system demand, in stressed hours.
- Reliability value is driven by fuel availability – wind or solar radiance – and load.
- Once a resource has been built, there is little that it can do to improve its performance.
  - There will be some natural variability performance within a class and this can be covered with the some sort of empirical true-up.
- The only way a resource can "secure" more wind or sun is through new construction or repowering.
  - A solar developer can elect to build a tracking array instead of a fixed, change inverter size, etc.
  - A wind developer can repower an existing farm with taller turbines or better power curves.

ELCC doesn't work for thermal because performance primarily depends on individual unit operations and economic choices.

- Many factors influence reliability for thermal resources, and these factors are largely economic in nature.
  - **Investment to improve reliability is highly fact-specific** and is influenced by many variables (e.g. weatherization, type and duration of dual-fuel capacity, reinforcing single points of equipment failure, age of existing equipment).
  - **Gas availability is highly fact-specific** based on a number of economic considerations (e.g., plant heat rate, gas interconnection arrangements, etc.).
- An existing thermal resource can improve its reliability by improving its weatherization, changing its fueling arrangements, modifying its maintenance practices, changing its air permit restrictions, and so on.
- Class-based ELCC/MRI approach necessarily lumps good and poor performers into one class, which reduces downside risk for poor performers, and limits accreditation value for good ones. Unit-specific adjustments can partly mitigate, but not eliminate, the bias.
- While a "perfect" ELCC might yield accurate accreditations, it is unlikely that any modeling exercise can capture the nuances of thermal operation (see appendix for example of the issues based on a recently published report).

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Consider LS Power's Wallingford Energy Center: A highly reliable gas-only power plant in CT *without* meaningful firm gas supply.

- LS Power reviewed over seven years (Dec-14 through Feb-22) of Wallingford's GADS submissions and operating data in response to the RENEW Complaint (EL22-42).
- We find that Wallingford runs hundreds of times a season. It runs in cold temperatures. It provides energy when asked with a near perfect record. Wallingford does not have issues securing fuel when needed. And, critically, it does all this without conventional firm fuel contracts.

Figure 2: Wallingford Output by Daily Average Temperature (Dec. 2014 – Dec. 2021)[38]

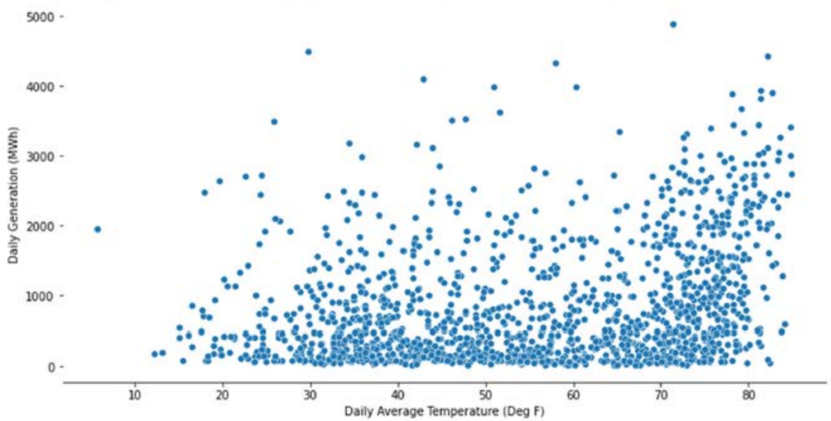

Table 1: Wallingford Winter Availability and Starts Across All Units (Dec. 2014 – Feb. 2022)[39]

Winter	Availability Factor	Number of Attempted Starts	Number of Successful Starts	Share of Starts Successful
2014/15	99.8%	112	112	100.00%
2015/16	98.0%	302	301	99.67%
2016/17	99.8%	242	242	100.00%
2017/18	95.9%	160	159	99.38%
2018/19	97.6%	171	171	100.00%
2019/20	99.4%	189	189	100.00%
2020/21	99.9%	188	188	100.00%
2021/22	94.5%	104	104	100.00%
Total	**98.1%**	**1,468**	**1,466**	**99.86%**

- On 3/29/2022, Wallingford came online *with no notice* despite other gas-only resources facing output restrictions due to fuel unavailability and a pipeline OFO (April PC COO Report at 15-16).
- **How do you fairly distinguish between high quality thermal resources and low quality ones?**

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A possible path forward: Weighted EAF

Proposed Design Principles

- For **enhanced accreditation for thermal resources**, a design should:
  1. Weight system stressed hours more heavily;
  2. Avoid diluting stand-alone performance (or non-performance);
  3. Ensure sufficient forward-looking market signals are created to incent investment in reliability;
  4. Ensure price signals for actual and expected non-performance would drive to a market exit; and
  5. Use class-average approaches to augment unit-specific metrics only when unit-specific metrics are inadequate.
- Enhanced accreditation must be aligned with **performance incentives** to ensure that expected resource performance is “trued-up” with actual performance in operational timeframe.

So…what to do? LS Power's Conceptual Hierarchy of Improved Accreditation for thermal accreditation.

ISO-NE	1. **Unit Specific Audits** – Identifies resource reliability in a moment in time but fails to capture distribution of availability over course of year and fails to capture correlated risks between different supply resources.
PJM	2. **UCAP Constructs using EFORd** – Captures unit specific availability over course of year but fails to capture correlated risk.
Nowhere	3. **Class-level ELCC/MRI –** captures correlated risk but weakens price signals and risks lumping poor performers with good ones, and may discourage generators from taking proactive steps to improve/maintain reliability because non-performance risk is socialized across the whole class.
Nowhere	4. **UCAP Constructs with more stringent availability metrics** – Sharpens the unavailability metric by including *all* unplanned outages, so that units that suffer from unexpected maintenance delays and other outages are awarded lower capacity accreditations.
Nowhere	5. **UCAP Constructs with more stringent availability *and a* better stress metric** – Sharpens the nexus between unavailability and system reliability. Where EFORd penalizes a resource for failing to start when asked, it does not distinguish between a forced outage when there are many substitutes and a forced outage when system is more stressed.
Nowhere	6. **UCAP Constructs with more stringent availability, better stress metric, and representation of outage variability** – Reflects how unit's contribution to system reliability depends not just on its own performance but *also* how its performance interacts with other resources when calculating ICR.
Nowhere	7. **Unit-specific ELCC/MRI** – Reflects how a class of units may perform but likely subject to neigh-impossible data requirements for reasonably accurate estimates.

PJM's UCAP approach offers a reasonable starting point for thermal accreditation, but can be further sharpened.

- For point of reference, in PJM thermal is current accredited based on its "unforced" capacity (UCAP) – installed capacity, adjusted for forced outages:

$$UCAP = ICAP \times (1 - EFOR_D)$$

- EFORd is a measure of how often a resource fails (i.e., goes on forced outage) when it is demanded (i.e., called to run).

- In their ELCC filing, PJM argued that that thermal ELCC can be approximated by UCAP, so:

$$ELCC\ Rating \approx UCAP = ICAP \times (1 - EFOR_D)$$

- An enhanced thermal resource accreditation, better aligned with ELCC, would want to correct these shortcomings with something along the lines of:

$$UCAP = ICAP \times (1 - Indivudal\ Performance\ During\ Stress\ - Outage\ Variability)$$

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Enhancing the EFORd Construct

- Both the "EFOR" and the "d" parts of EFORd can be sharpened for accreditation.
  - **"EFOR"** captures only forced outage or forced derate hours. Does not include other kinds of outages which could limit a unit's ability to contribute to system reliability.
  - "**d**" does not differentiate between instances when a unit is very valuable for system reliability (e.g. cold-snap or heat-wave) and when it is less valuable for reliability (a calm April day).
- LS Proposes that EFORd be shifted to EAFw.
  - **"EFOR" → "Equivalent Availability Factor" or "EAF"** which accounts for *all* unplanned outages, so units that suffer from unexpected maintenance delays and other outages are awarded lower capacity accreditations.
  - **"d" → Stress-Weighting "w"** which accounts for the relative stress on the grid during an outage (see next slide for details).

Measuring unit-specific performance in 3 easy steps: EAFw

$$UCAP = ICAP \times (1 - \mathbf{Indivudal\ Performance\ During\ Stress} - Outage\ Variability)$$

1. Identify hourly (or sub-hourly) unit availability using unit-specific data for a given interval (say 3-5 years)
   – All units ≥20 MW already submit this data to GADS.

2. Assess hourly system loss-of-load probability (LOLP) using a pre-defined curve describing the relationship between system reserves and system stress
   – This sort of curve underpins the ORDC in ERCOT and was also developed for PJM's ORDC enhancements.

3. Calculate the stress-weighted average availability for each unit by combining inputs from (1) and (2).

$$EAF_W = \frac{\sum_{i=1}^{n} LOLP_i \times EAF_i}{\sum_{i=1}^{n} LOLP_i}$$

Where,

i = actual interval

n = count of actual intervals for a given delivery period

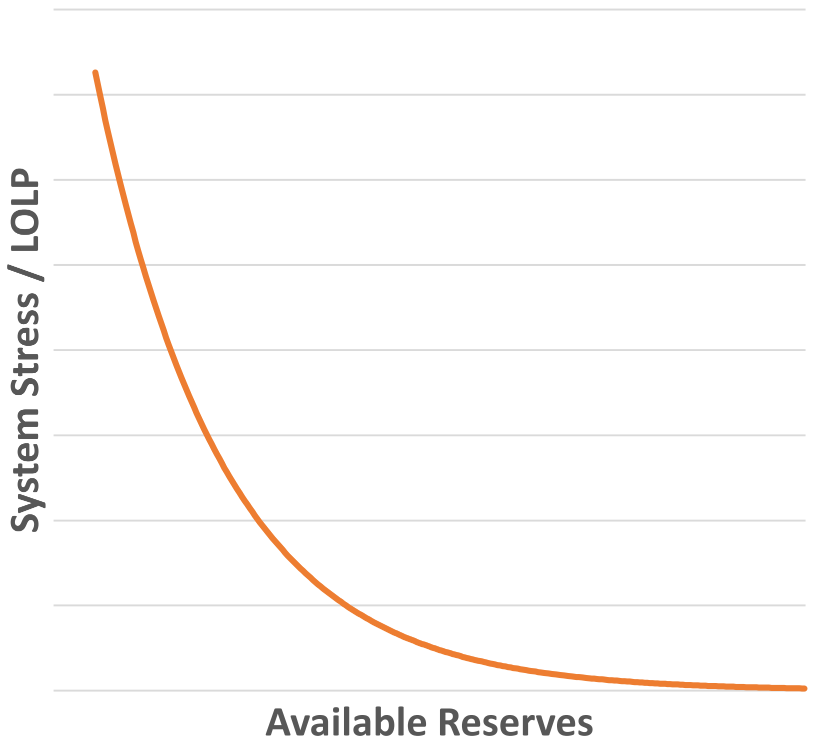
LOLP = loss of load probability for a given interval

EAF = equivalent availability for a given interval

Many well developed approaches to define relationship between LOLP and available reserves

$$UCAP = ICAP \times (1 - \boldsymbol{Indivudal\ Performance\ During\ Stress} - Outage\ Variability)$$

- Many methods to establish LOLP-reserve relationship analytically.
  - An LOLP curve defines the probability of load shedding occurring at a given reserve level.
  - To be clear, the LOLP-reserve relationship is a reliability identity, not a pricing tool.
- ERCOT [1] and PJM [2] already compute the LOLP-reserve relationship.
  - Relationship based on historical factors, including the probability of forced outages, probability of load forecast error and probability of wind forecast error.
- LOLP-reserve relationship can be “backed out” of stochastic models like GE MARS
- LS Power has no preference on the “right” curve at this conceptual stage.



[1a] https://lmpmarketdesign.com/papers/Hogan_ORDC_042513.pdf

[1b] https://www.ercot.com/files/docs/2013/10/03/568nprr_03_attachment_1___draft_methodology_for_implementing.doc

[2a] = https://www.pjm.com/-/media/committees-groups/committees/mic/2021/20210609/20210609-item-08-reserve-price-formation-ordc-education.ashx

[2b] = https://pjm.com/-/media/committees-groups/task-forces/epfstf/20180523/20180523-item-03-simplified-operating-reserve-demand-curve.ashx

Other Design Elements & Considerations

- **Q: How far-back should stress-weighting analysis look?**
  - **A:** 3-year look-back could reasonably cover range of weather while balance the duration that poor performance affects a resource's accredited value
- **Q: Under EAF_W, bad performance in non-stressed periods is not relevant. Should it be entirely discounted?**
  - **A:** No. We propose that the *higher* of EAF_D and $EFOR_D$ be used when setting UCAP. In ISO-NE, this means that all resources will likely receive a lower accredited value than under current rules, but some resources could get a significantly lower one if unit outages primarily occur during stressed intervals.
- **Q: What happens if there are no stressed intervals in study period?**
  - **A:** The proposal does not require that very tight conditions materialize because of the *relative* weighting scheme. Regardless, in the extreme case that the entire look-back period had no intervals with non-zero LOLP, the default $EFOR_D$ would be used.
- **Q: Should any kind of unplanned outage be excused when computing EAF_W?**
  - **A:** No. In fact, we have added maintenance outages, short-duration outages that the generator is able to postpone, to the metric to shift the risk of taking such outage to the generator.

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One complication: Include impact of systemic risk from outage variability in individual resource accreditations.

$$UCAP = ICAP \times (1 - Indivudal\ Performance\ During\ Stress\ - \mathbf{Outage\ Variability})$$

- What is outage variability?
  - Outages vary from hour-to-hour so, for example, a system with a 5% average outage rate might have 2% outage in some hours and 7% in others.
  - If thermal resources are accredited based on their unit-specific performance then the entire system is deficient capacity because of the probability of overlapping outages.
  - Traditionally, system planners embed a higher reserve margin in ICR capacity requirements to account for this outage variability, which results in load directly paying for this risk.
- We propose to use ELCC to compute a class-average outage variability component and add this result to the unit-specific metric as an adjustment, termed $Adj_{Asym\ Outages}$
  - Shifting impact of class-wide outage variability to suppliers aligns with current and proposed accreditation of intermittent resources

Summary

- **Put together, enhanced thermal resource accreditation would be:**

$$UCAP = ICAP \times (1 - Indivudal\ Performance\ During\ Stress\ - Correlated\ Risk)$$
$$= ICAP \times \left(1 - EAF_W - Adj_{Asym\ Outages}\right)$$

- The EAF_W concept:
  - is an improvement on the current audit- or EFOR-based approaches because it focuses on periods of system stress – aligning with how ELCC assesses reliability value of intermittent and duration-limited resources during periods of system stress.
  - provides a stronger link between incenting investment in reliability and unit-specific performance, both actual and forecasted.
  - is readily implementable because it relies on established economic theory and leverages known analytical techniques.
- The $Adj_{Asym\ Outages}$ concept:
  - allocates correlated risk to suppliers and away from load – aligning treatment of this risk with renewable resources assessed with ELCC.

Contact Information

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Appendix: Comments on the AEE / Astrape Report

AEE's thermal accreditation work offers an interesting concept that suffers from methodological flaws & unit allocation inefficiencies.

Report implicitly highlights the difficulty of extending ELCC to conventional generators.

- Recent work sponsored by AEE contemplates extending ELCC-type techniques to thermal resources.
  - Considers system four kinds of new risks over and above to current accreditation including **(1)** outage asymmetry, **(2)** common mode failures, **(3)** weather dependent outages, and **(4)** fuel availability outages.
  - When all correlated outages are considered, **AEE suggests winter de-rates in excess of 20%,** despite a 5% forced outage rate.
- Report is an interesting thought piece but highlights the difficulties of extending market-based ELCC to thermal because:
  - Common-mode and fuel-supply outages are highly fact specific and not generalizable.
  - Weather dependent outages are highly variable on a unit-level.
  - Even if a high-quality class ELCC can be developed (uncertain), no obvious method to allocate class results to specific resources.

Thermal Generator SUMMER	Outage Factor	Accreditation Impact (Incremental)	Capacity Credit (Cumulative)
Standard Practice	Forced Outage Rate	5.0%	95.0%
Proposed Additional Factors	Outage Variability	4.6%	90.4%
	Common Mode Outage	N/A	
	Weather Dependent Outage	5.6%	84.7%
	Fuel Supply Outages	N/A	
Adjusted Summer Thermal Capacity Credit:		84.7%	

SOURCE: Astrapé Consulting, "Accrediting Resource Adequacy Value to Thermal Generation," March 2022

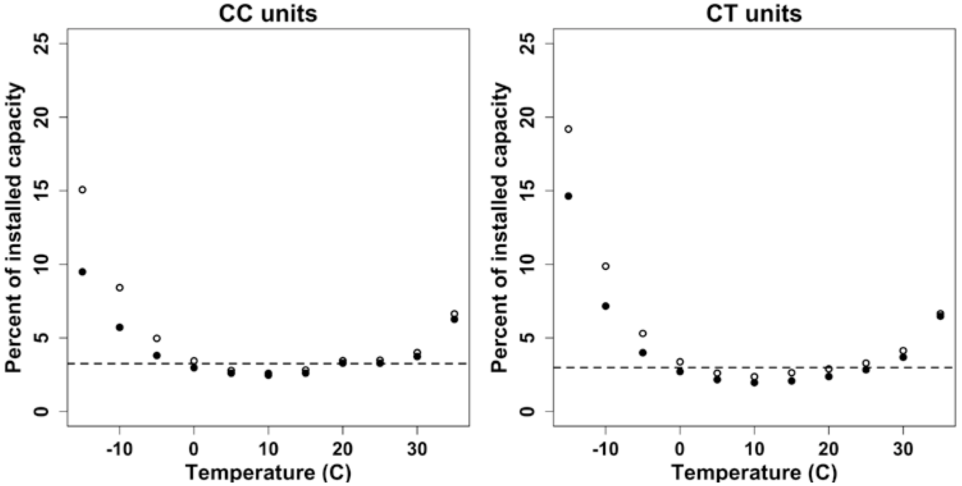
Thermal Generator WINTER	Outage Factor	Accreditation Impact (Incremental)	Capacity Credit (Cumulative)
Standard Practice	Forced Outage Rate	5.0%	95.0%
Proposed Additional Factors	Outage Variability	2.7%	92.3%
	Common Mode Outage	2.3%	90.0%
	Weather Dependent Outage	10.0%	82.3%
	Fuel Supply Outages	6.2%	76.1
Adjusted Winter Thermal Capacity Credit:		76.1%	

1. Astrape Consulting, *Accrediting Resource Adequacy Value to Thermal Generators,* March 2022, https://www.aee.net/aee-reports/getting-capacity-right-how-current-methods-overvalue-conventional-power-sources

Concern #1: Astrape double-counts fuel supply constraints

Murphy (2019)'s cold-weather outage estimates already included fuel unavailability.

- Astrape report speculates that **weather-dependent outages** are separate and distinct from **fuel-supply outages.** [Report at 16]
  - "The weather dependent outages identified in the Sinnott Murphy report appears to only be identifying outage correlations with extreme hot and cold temperatures. However, during extreme cold weather events, there is an additional impact on the availability of fuel itself…" (Report at 34).
- But, the Murphy study *already* included fuel-supply outages as part of its overall temperature dependent outage estimates.
  - Per correspondence with Murphy, about 40% of cold-weather outage is due to fuel unavailability.
- So, by layering fuel constraints on top of the weather-dependent outage estimates, **Astrape is double counting fuel supply constraints (in part or whole).**



Murphy Fig. 6. Sensitivity: *Expected levels of unavailable capacity as a function of temperature, with and without fuel supply outages.*

- Hollow circles are presented in the main report and *include* all outages, including fuel unavailability events.
- Solid circles *exclude* fuel unavailability events.

Fuel unavailability events defined using three GADS codes (9130, 9131, 9134) which relate to physical fuel supply disruptions or fuel conservation, not fuel system mechanical issues.

Sinnott Murphy, Fallaw Sowell, Jay Apt, *A time-dependent model of generator failures and recoveries captures correlated events and quantifies temperature dependence,* Applied Energy, Volume 253, 2019, https://doi.org/10.1016/j.apenergy.2019.113513.

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Concern #2: Astrape extrapolates temperature dependent outages far beyond the research it is based on.

- Astrape estimates **weather-dependent outages** down to -15 Deg F (Report at 14)
  - Starts with estimates from Murphy (2019), which estimates down to -15 Deg C (5 Deg F).
  - Then, Astrape extrapolates outage rates down linearly to -15 Deg F
- **Extrapolation inflates maximum outage rate for CTs from 16% to 28% and CCs from 11% to 19%.**
- Astrape does not justify their extrapolation.
- Murphy cautions that there is very little outage data below 5 Deg F, so colder estimates are mostly parametric extrapolation, not physical observations.
- **Astrape's extrapolated region *also* implicitly includes significant fuel-related outage rates.**

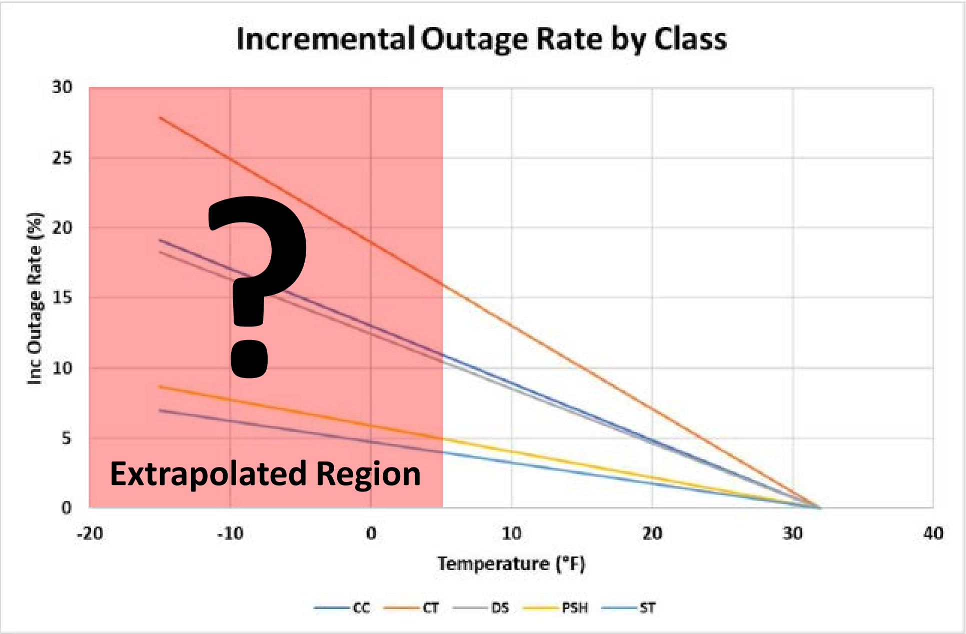

Figure ES3. Cold Weather Outage Assumptions

Concern #3: Astrape elides significant intra-class variability

- Astrape indicates that class-level adjustments can be applied directly to resources within each class.
  - For example, Astrape indicates that weather-dependent outages should reduce portfolio accreditation by 12.7%
  - Astrape *also* indicates that a specific unit, the Hopewell CC, should be reduced by the same 12.7% to account for weather-dependent outages. (Report at 40).
- Murphy (2019) – on which these values are based – found that there is significant variance in unit reliability (i.e., a few were very unreliable and many were very reliable); see chart to the right.
- **Does not make sense to apply a fixed / average derate to all resources in a class given significant variability between resources.**
  - If thermal ELCC pursued, more work needed to develop high quality class-unit allocators.

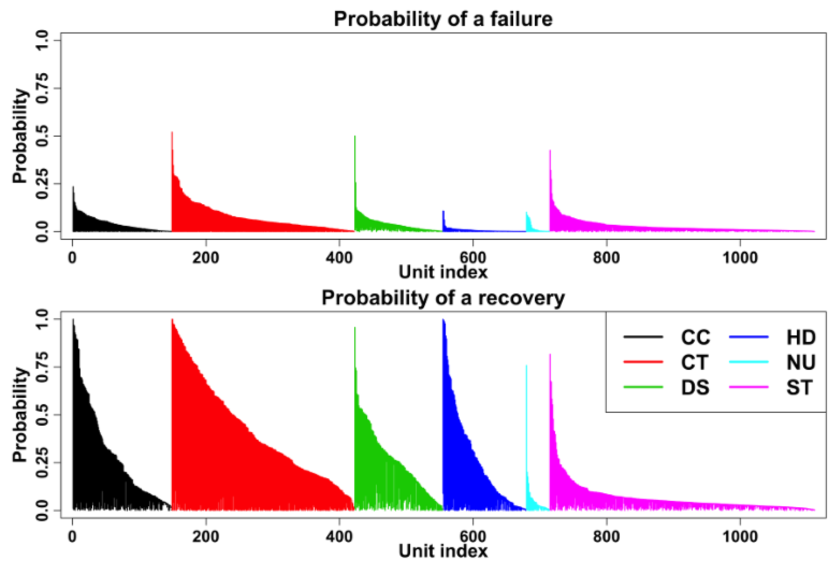

Figure A.12: Summarizing the empirical range of hourly transition probabilities (1995-2018 model fits). *Plots include 1,111 generators with at least 10 failure and recovery events per statistically significant model parameter. Each generator is represented as a vertical line at an integer index (1 to 1,111). In each plot, generators are sorted by generator type and maximum experienced transition probability. Black is combined cycle gas (CC), red is simple cycle gas (CT), green is diesel (DS), blue is hydroelectric (HD), cyan is nuclear (NU), magenta is steam turbine (ST).*

1. Sinnott Murphy, Fallaw Sowell, Jay Apt, *A time-dependent model of generator failures and recoveries captures correlated events and quantifies temperature dependence,* Applied Energy, Volume 253, 2019, Supplementary Materials, https://ars.els-cdn.com/content/image/1-s2.0-S0306261919311870-mmc1.pdf